Mosses and liverworts of the Chocó region, Colombia.

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Abstract: The Chocó region in Colombia is one of the wettest rainforests regions in the world. Isolated for about 3 million years, it is known for its high rate of endemism in flowering plants, ferns, birds and butterflies. Bryophytes (mosses and liverworts) of this region, however, were very unsufficiently known. For this reason, a first survey of the bryoflora of the Chocó region was made in 1992 along a transect from sea level to 1800 m elevation. Apparently because of the high precipitation with up to 12 m annual rainfall, terrestrial species were found growing on bark or corticolous species on leaves. The cover of epiphytic bryophytes is higher than elsewhere, especially in the lowland forest which shows usually a low bryophyte cover. The percentage of mosses compared with that of liverworts is much lower than elsewhere. Mosses form only about 10% of the bryophyte cover in contrast to 40-50% in the according elevation in other rain forest regions.

Introduction

The pacific coastal region of northern Ecuador, Colombia and Panama is one of the most interesting biogeographical regions in the world, which is named after a Colombian department Chocó region. It is (still) densely covered by rain forests stretching from the Pacific coast up to the slopes of the Andes (figs. 1-4). This area is of remarkable biological interest and known for its "high species diversity and strikingly high rates of endemism" amongst flowering plants, ferns, birds and butterflies[8]. There are two reasons for this exceptional biogeographical interest and species richness: first, the Chocó region has been isolated from the rest of South America for a long time due to the uplift of the Andes in Tertiary. Therefore the fauna and flora of this region has been trapped between the Pacific Ocean and the Andes for several million years. Furthermore, it is one of the wettest rain forests in the world with up to 12.000 mm/year and even 15.000 mm in some places.

Studies by Drs. Enrique Forero [4,5,6] and Alwyn H. Gentry [8,9,10] from the Missouri Botanical Garden have provided much valuable information about the flowering plants and the ferns of the region. However, the mosses and liverworts of this region remained largely unexplored. Catalogues of the mosses [1] viz. hepatics [11] of Colombia list forty nine species of mosses and forty-five species of liverworts for the Chocó Department. In other departments such as Cundinamarca, 500 species of mosses and 450 species of liverworts are known. (For comparison, the total mossflora of Colombia consists of about 900 species). One reason for the unsufficient exploration is the difficult access to this region; most parts are only accessible by mules, canoes or planes. Other reasons are the unpleasant climate with heavy rainfalls as well as guerilla activities.

The very poor knowledge of the mosses and liverworts of the region lead to the plan of a first preliminary floristic study of the mosses and liverworts. Although the department of Chocó has a size of 47205 km^2 and can hardly be explored in a reasonable time, some representative data should be gathered. Therefore a study was made along a transect from the coast to the montane forest of the Andes in July and August 1992, along which inventories of 10 hectarplots in different elevations were made. The study should provide data which could be compared with ferns and flowering plants, clarify the degree of endemism amongst bryophytes and give insights of the geographical affinities to other regions. Furthermore the influence of the high precipitation on the ecology of mosses and liverworts should be studied. The results concerning mosses were published two years later [12].

Results

ECOLOGICAL EFFECTS OF HUMIDITY

The Chocó region as the rain forest region with the highest precipitation in the Neotropics allowed to observe the effects of the high humidity on the bryophytes.

The first surprising and unexpected result was that **liverworts represent up to 90% of the bryoflora**, an effect, which has not yet been observed so far and is presently unique in the world. It is well known that liverworts indicate humid climates. The ration liverworts: mosses of certain floras is calculated for an index expressing the oceanity of the bryophyte vegetation. However, in the wettest montane rainforest in the Neotropics studied so far, liverworts count for „only“ 50-60% of the bryophytes. The overwhelming mass of liverworts was the reason that the collections of liverworts have not yet been studied in detail and furthermore many genera are unsufficiently known and in need of revisions. For example, in the genus *Plagiochila* (fig. 8-9) more than 1000 species have been described worldwide, of which more than a half occur in the neotropics. Therefore the present evaluations are only based on mosses. Alltogether about 350 specimens of mosses and about 1000 specimens of liverworts were collected. The 350 specimens of mosses belonged to 125 species which were used as a base for the phytogeographical evaluation.

A second effect concerns the **altitudinal zonation**, a depression of altitudinal belts of 300 - 400 m. This phenomenon is known from high oceanic parts of temperate regions (e.g. British

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Columbia, Scotland, Ireland) but has not yet been observed in the tropics except on small islands. Thus submontane species could be observed at sea level or high montane species already at 1800 m. Species of the liverwort genus *Herbertus*, usually growing in the understorey of high montane forests, were found in the canopy of the lowland forest.

The **phytomass of bryophytes** in tropical rain forests usually increases with altitude. The lowland rainforest harbours only few species in low quantities, which is caused by high temperatures and low light intensity, as gas exchange experiments in growth chambers have shown. At higher altitudes, species numbers and phytomass increase. According to the depression of vegetation belts, we have a rich bryophyte flora already at sea level.

At least, a **change of substrates** was observed as a result of the high humidity. Species usually growing on bark were found on leaves, unusually many species growing on soil were found on bark and many species were colonizing even small twigs (fig. 11).

ENDEMISM

The Chocó region is known for high rates of endemism in flowering plants. About 20% of all species shall be endemic[1]. Twenty-six percent of the species which were found in the Rio Palenque area [2], a refuge of 167 ha in the pacific lowland of Ecuador at about 200 m sea level, are endemic to coastal Ecuador and Colombia. High endemism concerns also pteridophytes, of which 15% of the species occurring in the Chocó department shall be endemic[8], which is an extraordinary high rate for spore plants. However, the collections of mosses and liverworts indicate the presence of only a few endemic species. Only four endemic mosses were found, which is in sharp contrast to the high rate of endemism of flowering plants. Two of them (*Porotrichum frahmii* Enroth, *Holomitrium aberrans* Frahm) were found as new to science during our fieldwork. In addition, 17 species of mosses were found as new for Colombia. There are also 4 species of liverworts known as Chocó endemics. One of them, *Fulfordianthus pterobryoides*, is a conspicuous large species, up to 5 cm high, growing on twigs (fig. 13). Although more intensive fieldwork will probably reveal a few more new endemic species, the rate of endemism of flowering plants will surely not be reached. Conspicuously all the endemic species are epiphytes, which are regarded as the youngest branches of bryophyte evolution. The low rate of endemism in mosses and liverworts can be explained by the fact that these plants are very ancient and conservative in their characters. They originated already in the Palaeozoic and had a relatively slow evolution. It cannot be excluded that some infraspecific categories evolved in the Chocó region, probably not only as a result of isolation but as an adaptation to the high precipitation, but this has to be confirmed.

PHYTOGEOGRAPHICAL ELEMENTS

The composition of phytogeographical elements of bryophytes are different from those of flowering plants. Bryophytes have usually much wider ranges, which reflects spore dispersal and also much older phylogenetic age. The phytogeographical evaluation of mosses revealed that about 60 % belong to the main neotropical element. Pantropical, cosmopolitan and species occurring in tropical America as well as in tropical Africa count for 12%. The andine element is

present with 6 %. Interesting is that the meso-american element is present with 15% of all species. This includes all species occurring in Central America, or the Caribbean or the north coast of South America. This is possible because the Chocó region opens northwards with the valley of Rio Atrato, which drains to the Caribbean Sea and provides easy access for migration to the south.

The composition of phytogeographical elements varies in the different altitudinal belts. The andine element is only present above 1200m, the percentage of neotropical elements is with 70-80% highest below 500 m, the meso-american element is highest in the lowlands, where possibilities for migration from Panama and the Caribbean exist. The endemics are scattered between 200 and 1600 m and are thus predominantly not lowland elements, whereas the endemic flowering plants and ferns are concentrated in the coastal lowland.

ALTITUDINAL ZONATION

Altitudinal belts were determined using determination of floristic discontinuities. This method calculates the numbers of the lowermost and uppermost occurrences of species within a transect for each altitude[10]. Altitudes with the highest number of species have the most drastical floristic turnover and indicate a change in the vegetation belt. The highest floristic discontinuities were found at 200 m and 1500 m, separating a tropical lowland forest (< 200 m) from a submontane (200 - 1500 m) and a lower tropical forest (> 1500 m). These altitudinal belts agree with results of studies in Peru with the same method, estimations of the percentage cover of bryophytes in Colombia or the phytomass of epiphytic bryophytes in Borneo[7].

The number of species of mosses increases from about 20 per study site in elevations up to 700 m to about 30 above and a maximum of 39 at 1500 m which reflects a general tendency in tropical rainforests.

Conclusions

The rain forests of the Chocó region of Colombia with the highest precipitation in the Neotropics have caused severe ecological changes for the bryophytes. This concerns a predominance of liverworts, a depression of altitudinal belts with anusual species richness and high phytomass already at low elevations and a shift of substrates from soil to bark and from bark to leaves. These effects have so far not observed elsewhere in tropical rain forests. A special phytogeographical rôle of the Chocó region is not supported by bryophytes. Bryologically, in terms of mosses, the Chocó region can be defined as an extension of the Caribbean and Central American mossflora along the western side of the Western Cordillera in Colombia and northern Ecuador. This is easily to explain since the Chocó region drains to the Caribbean and is not separated from the lowlands of Panama. Although there exist a few endemic bryophytes in the Chocó region, the rate of endemism is not significantly higher than elsewhere.

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1. *The lowland forest with Rio Atrato.*

2. *The dense, almost undisturbed lowland forest from the plane. Large parts are (still) not accessible by roads and only inhabitet by a few indians.*

3. *Pacific slope of the Andes of the Chocó region.*

4. *Steaming humidity is characteristic for the Chocó region.*

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5. *A species of* Bazzania, *a genus of liverworts characteristic for the montane rain forests.*

6. *Male plants of the thallose liverwort* Monoclea gottschei. *With a length of up to 20 cm, this species is one of the largest liverworts in the world.*

7. *Epiphyllous liverworts growing on a leaf in the understorey of the Chocó rainforest. The surface of the leaf is densely covered with liverworts as seen from aside. Whereas epiphyllous liverworts usually grow prostrate on the leaves, the liverworts in the Chocó region grow upright because of the high humidity.*

8. *A species of* Plagiochila *with brownish tinge.*

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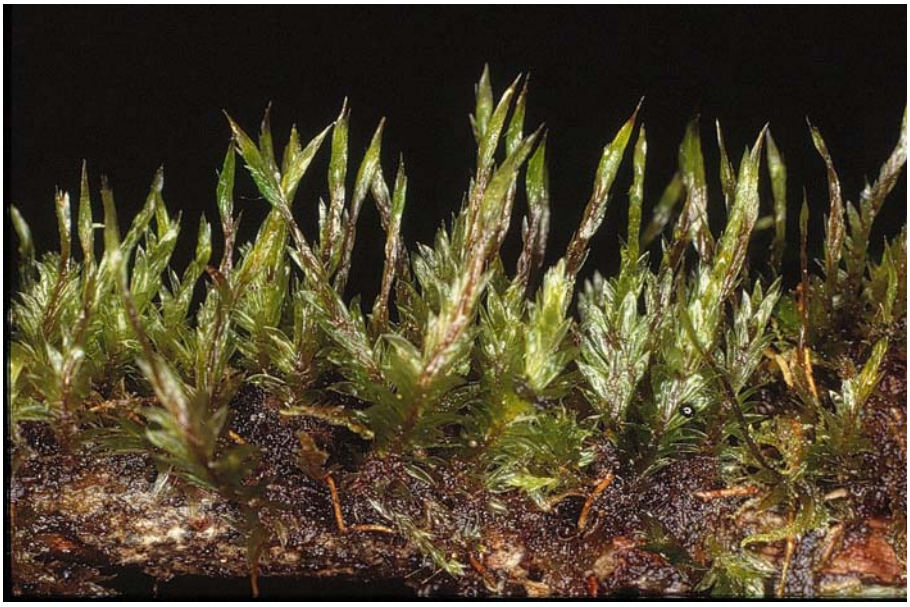
9. *Plagiochila is one of the species richest liverwort genera in the Neotropics. Left: Plant of* Plagiochila macrotricha. *The leaf borders are longly ciliate and seem to function for condensation of water. Right: Male plants of* Plagiochila spec. *with microphyllous branches bearing the male sex organs (antheridia).*

10. Cyclolejeunea peruviana *growing in dense mats on a leaf.*



11. *The moss* Acroporium pungens *usually grows on rotten wood. Due to the high humidity in the Chocó rainforests, it inhabits even small twigs.*

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12. *Left:* Cyclolejeunea *produces lentiform broodbodies, which have a sticky surface and are glued on the smooth surfaces of other leaves. Right: The moss* Orthostichopsis tetragona *characteristically grows on twigs in the canopy.*

13. *The liverwort* Fulfordianthus pterobryoides *is one of the 4 liverwort species known to be endemic to the Chocó regions. It grows on twigs of treelets in the understorey.*

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